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WEATHER TYPES AT SELECTED METEOROLOGICAL STATIONS IN SIBERIA

Abstract: This paper presents the structure of weather types at four Siberian synoptic stations: Ostrov Kotelnyj, Verkhoyansk, Oymyakon and Yakutsk. The analysis has been performed on the basis of data published in the Internet database of synoptic messages OGIMET for the period of December 1999 to November 2013. Types of weather were determined based on the modified classification of weather types by Ferdynus (1997, 2004, 2013). The occurrence of particular groups, classes, and types of weather, and sequences of days with predominant weather types was identified. During the research period the structure of the weather types at the selected stations is characterized by a large number of observed types of weather, with the majority of them occurring with a low frequency. Frosty weather was predominant. The most frequently reported was the weather marked with numerical code 1100 (extremely frosty, clear without precipitation and calm) in Verkhoyansk (12.5%), 1300 (extremely frosty, cloudy without precipitation and calm) in Yakutsk (12.2%), 1200 (extremely frosty, partly clouded without precipitation and calm) in Oymyakon (11.6%) and 2201 (exceptionally frosty, partly clouded without precipitation and light breeze) in Ostrov Kotelnyj (6.7%).

Key words: complex climatology, weather types, Siberia

Introduction

According to the principles of complex climatology, in order to fully characterize the climate of a particular place, it is necessary to analyse the frequency of the occurrence of weather conditions (referred to as weather types) and their recurrence over time. A "weather type" is a set of generalized weather characteristics, which is expressed in the character and gradation of selected meteorological elements (Woś 2010). According to several climatologists, the interdependence of meteorological elements and their total comprehensive impact within a given geographical environment enables the description of the climate conditions of an area to be supplemented and expanded: analysis of the climate based merely on the mean values of multiannual climatic elements does not provide a complete picture of the phenomenon (Piotrowicz 2010). The application of complex climatology methods has been thoroughly described in the literature (Howe 1925; Nichols 1925; Chubukov 1949; Kossowski 1968; Maheras 1984; Marsz 1992; Woś 1996, 2010; Ferdynus 1997, 2004, 2013; Michailidou et al. 2009).

The purpose of this study is to determine the basic structural elements of weather conditions occurring at the four Siberian synoptic stations: Ostrov Kotelnyj (WMO No 21432, latitude 75°26'N, longitude 137°52'E, altitude 10 m a.s.l.), Verkhoyansk (24266, 67°33`N, 133°23`E, 137 m a.s.l.), Oymyakon (24688, 63°15 `N, 143°11`E, 745 m a.s.l.) and Yakutsk (24959, 62°01`N, 129°43`E, 103 m a.s.l.) (Fig. 1). The research is complemented by an analysis of the annual variation of separate groups, classes and types of weather. Changes in the frequency and type of weather in the defined area are not only very interesting from a cognitive point of view, but also very important in terms of their potential application, which may involve actions impacting on many areas of human life, from energy, transport and road maintenance to changes in climatic conditions and their consequences. The Siberian sector of the Arctic and Eastern Siberia were selected for analysis because there is little knowledge of the structure of the weather types and their regional variations in this area, so the results of this work should be of considerable significance. Moreover, Siberia is a very interesting area, with the most extreme continental climate on earth, which in winter is primarily determined by the Siberian High. Low pressure systems rarely occur in this region. The lowest air temperatures in the northern hemisphere have been noted at the stations of Oymyakon and Verkhoyansk, despite their location outside of the Arctic (Przybylak 2003). Kotelnyj Ostrov station is located within the New Siberian Islands in the Arctic Ocean and, in accordance with the classification of climate by Köppen, it represents the type of polar tundra climate, ET. The other stations: Verkhoyansk, Oymyakon and Yakutsk, situated on the Asian continent, have a subarctic continental climate with extremely frosty winters Dfd (Martyn 2000).

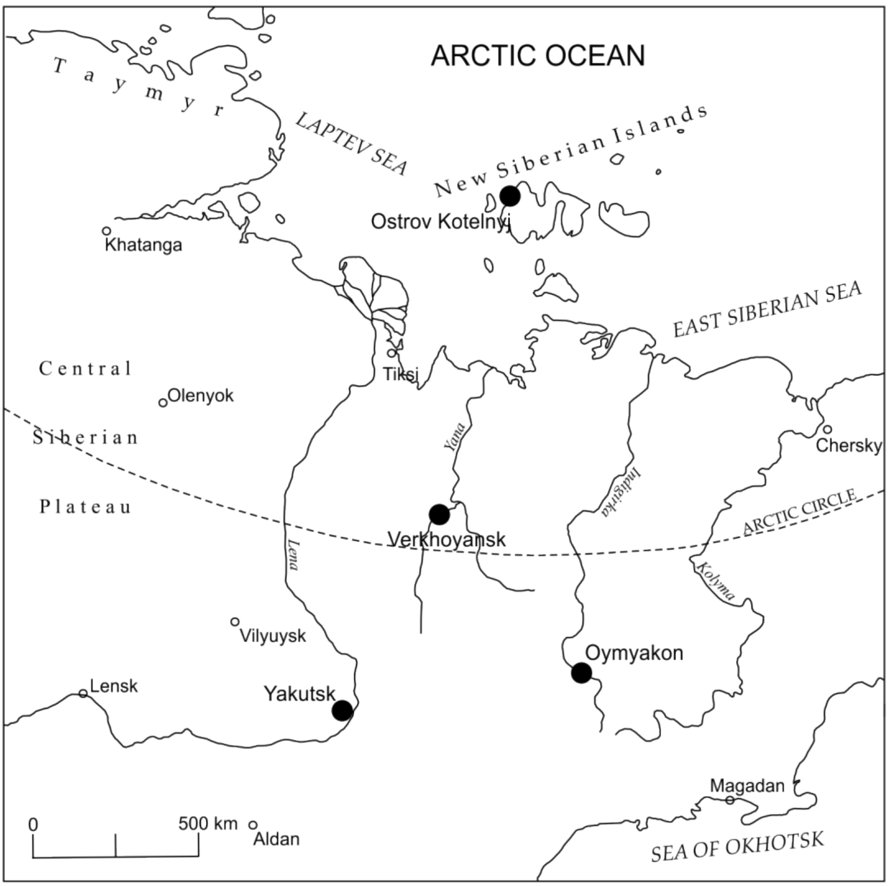

Fig. 1. Location of the Siberian meteorological stations used in this article

Data and methods

The data examined in this study covers the period of December 1999 to November 2013 and comes from the database of synoptic messages SYNOP provided by OGIMET service (Valor and López 2014). However, there are some gaps in the source data. The greatest proportion of the missing data relates to the Ostrov Kotelnyj station. The test period of 5114 days is lacking 154 days (3.01% of total days). For the other stations the missing data is much less. In the case of Verkhoyansk, the missing number is 42 days (0.82%), and in Oymyakon it is 27 days (0.53%), whereas the data set for Yakutsk is complete. In the New Siberian Islands, a greater percentage of missing observation occurs in colder months of the year (9.68% in January, 4.80% in February, 6.43% in September and 4.15% in October). In the remaining months the missing data does not exceed 2.30%. The reason for this lack is probably the periodic occurrence of weather conditions which are extremely difficult both for the people involved in the measurements and for the measuring equipment, which may then fail. At the other stations the missing data relate to individual days and do not show any seasonal regularity.

Although the data set is not complete, it has been decided to employ the material to determine the structure of the weather types at the selected stations. What supports this decision is the fact that in determining the weather structure, annual, monthly and decadal mass data is interpreted, which, once the classification has been completed, constitutes the base for calculating the frequency of the occurrence of a given classification unit of „weather type." Please note that the terms „decade" and „decadal" refer in this article to a 10-day period. Since the year, month, or decade is the basic unit of grouping weather types, the order of occurrence of various weather types in a month or year is not very significant. What provides the comparability of the results is the measure of frequency of the occurrence of a „weather type" as a percentage (relative value). Although the precision of the obtained results is lower, they do produce approximate results. Considering the fact that the percentage of the missing data in the data set is relatively small, it can be assumed that in the case of this work the approximation will contain a minor error, and therefore will be relatively close to reality.

The weather types at the selected Siberian stations were determined on the basis of the existing method for classifying weather types in polar regions by Ferdynus (1997, 2004, 2013). The use of the Ferdynus classification allows results to be obtained which it is feasible to compare with the previously conducted studies on the structure of types of weather in the Subantarctic (March 1992) and the Atlantic sector of the Arctic, (Ferdynus 1997, 2004, 2007, 2013). Classification of the weather types was based on daily observations, and the following meteorological elements were taken into account:

- the average daily air temperature (T_{avg}), the minimum (T_{min}) and maximum (T_{max}) daily air temperature,
- the average daily total cloud amount in octas (N),
- the daily precipitation amount (R)
- the average daily wind speed (V_{avg}) and the maximum gusts of wind (QNT) during the day (V_{max}).

For the purpose of characterizing thermal conditions, the following were determined: 10 ranges of average daily air temperature; 3 ranges of total cloud amount (on the scale of 0–8); 2 ranges of precipitation, and 9 ranges for wind speed. For each range, the conventional numeric codes presented in Table 1 were introduced.

This constituted the basis for the classification of weather types. Each weather type is marked with a numeric code consisting of 4 digits. The first digit denotes thermal conditions (T), the second refers to the total cloud amount (N), the third to precipitation (R), and the fourth to wind (V). As a result of the combination of the selected weather parameters, and various possible gradations of their values, 480 potential types of weather (TNRV) were created.

The basic taxonomic unit of this classification is the weather type. It groups all days which have identical characteristics of all of the four meteorological elements. The author has also separated two auxiliary units; the first is the “weather class”, comprising days with identical descriptions for the 3 parameters: cloudiness, precipitation and wind speed. The second is the “weather group”, characterized by an identical description of thermal conditions.

Modification of the classification by Ferdynus (2004, 2007, 2013) involved changing the scope of the thermal range assigned with a value of 1 (extremely frosty). In the standard classification by Ferdynus this section is characterized by a range of average daily air temperature of -30.0°C to -39.9°C. Due to the fact that in Siberia in the winter months the average daily air temperature drops below -40°C, in this work the lower limit of this range has been left open ($T_{śr} < -30.0$°C).

Table 1. Weather classification after Ferdynus (2004), slightly modified

Weather element	Numeric Code	Name of weather	Partition
Air temperature (T)	0	exceptionally warm	$20.0°C \le T_{avg} \le 29.9°C$, $T_{min} \ge 0°C$
	9	very warm	$10.0°C \le T_{avg} \le 19.9°C$, $T_{min} \ge 0°C$
	8	warm	$5.0°C \le T_{avg} \le 9.9°C$, $T_{min} \ge 0°C$
	7	moderately warm	$0.0°C \le T_{avg} \le 4.9°C$, $T_{min} \ge 0°C$
	6	transitional (frost-thaw)	$T_{min} \le 0°C$, $T_{max} > 0°C$
	5	moderately frosty	$-4.9°C \le T_{avg} \le 0.0°C$, $T_{max} \le 0°C$
	4	frosty	$-9.9°C \le T_{avg} \le -5.0°C$, $T_{max} \le 0°C$
	3	very frosty	$-19.9°C \le T_{avg} \le -10.0°C$, $T_{max} \le 0°C$
	2	exceptionally frosty	$-29.9°C \le T_{avg} \le -20.0°C$, $T_{max} \le 0°C$
	1	extremely frosty	$T_{avg} \le -30.0°C$, $T_{max} \le 0°C$
Cloudiness (N)	1	clear	$0.0 \le N \le 2.0$
	2	partly clouded	$2.1 \le N \le 5.9$
	3	cloudy	$6.0 \le N \le 8.0$
Precipitation (R)	0	no precipitation or precipitation < 0.1 mm	R = 0 mm and trace of precipitation
	1	precipitation	R > 0 mm
Wind (V)	0	calm or light air	$0.0 \le V_{avg} \le 1.5\ ms^{-1}$
	1	light breeze	$1.6 \le V_{avg} \le 7.9\ ms^{-1}$, $V_{max} < 11\ ms^{-1}$
	2	light breeze with periods of strong breeze	$1.6 \le V_{avg} \le 7.9\ ms^{-1}$, $V_{max} \ge 11\ ms^{-1}$
	3	strong breeze	$8.0 \le V_{avg} \le 16.9\ ms^{-1}$, $V_{max} < 17\ ms^{-1}$
	4	strong breeze with periods of gale	$8.0 \le V_{avg} \le 16.9\ ms^{-1}$, $V_{max} \ge 17\ ms^{-1}$
	5	strong breeze with periods of storm	$8.0 \le V_{avg} \le 16.9\ ms^{-1}$, $V_{max} \ge 30\ ms^{-1}$
	6	gale	$17.0 \le V_{avg} \le 29.9\ ms^{-1}$, $V_{max} < 30\ ms^{-1}$
	7	gale with periods of hurricane	$17.0 \le V_{avg} \le 29.9\ ms^{-1}$, $V_{max} \ge 30\ ms^{-1}$
	8	hurricane wind	$V_{avg} \ge 30\ ms^{-1}$

The days classified into weathers have been grouped, and average annual, monthly and "decadal" frequencies of the occurrence of individual classification units and sequences of days with the same weather types have been determined. Note again that "decade", in this study, means a ten-day period. Each month of the year has been divided into 3 decades, the first decade includes the first 10 days of the month, the second from the 11th to the 20th day of the month, and the third from the 21st to 28th, 29th, 30th or 31st, depending on the length of the month). Moreover, for each station the core of the structure of weather types was specified. As in the previous work of the author (Dobrowolska 2013) the core is formed by the types of weather which, when put in order of decreasing frequency of occurrence, represent the top 70% of all the observations.

Structure of weather types

Frequency of occurrence of weather groups

A weather group consists of days uniform in terms of thermal conditions. At all Siberian stations, except for Ostrov Kotelnyj (Siberian Arctic), each of the ten individual weather groups occurred in the research period. At the Ostrov Kotelnyj station no days of exceptionally warm weather (0NRV) were recorded, even though the daily maximum temperature is 25.1˚C (Klimat Ostrova Kotelnyj 2014). In Verkhoyansk (33.8%), Oymyakon (34.4%) and Yakutsk (25.0%), extremely frosty weather (1NRV) was most often observed, while in Ostrov Kotelnyj exceptionally frosty weather was most common (2NRV, 25.7%). The second in terms of frequency in Verkhoyansk (17.5%) and Yakutsk (20.4%) was very warm weather (9NRV). Therefore, nearly half of the days of the analysed period are constituted by the two extreme weather groups. This points to the continental character of the climate of these stations. In Oymyakon very warm weather had a frequency of 17.3%, and was second in frequency only to transitional weather (frost-thaw) (6NRV, 18.9%). The frequency of this group is significant, and occurs to a similar extent in the structure of weather groups at all the stations. In Verkhoyansk it was recorded with a frequency of 15.4%, 15.0% in Yakutsk and 13.8% in the New Siberian Islands. In Ostrov Kotelnyj, during almost one fifth of the days, very frosty weather was found (3NRV, 17.1%). The smallest number of days was characterized by very warm weather (9NRV, 0.6%)

at the Ostrov Kotelnyj station, whereas in Verkhoyansk, Oymyakon and Yakutsk it was moderately frosty weather (5NRV, 1.2%, 0.7%, 1.3%, respectively) and moderately warm weather (7NRV, 1.7%, 1.1%, 1.4%, respectively).

Ostrov Kotelnyj stands out for its predominance of frosty weather (1NRV, 2NRV, 3NRV, 4NRV, 5NRV) in the annual pattern of weather groups (69.9%). In Verhoyansk and Oymyakon slightly more than half of the days in the year are days with frosty weather groups (55.1% and 54.9%). In Yakutsk this weather group constitutes 48.8% of all days. The greatest number of days with the warm weather groups (1NRV, 2NRV, 3NRV, 4NRV, 5NRV) was reported in Yakutsk (36.3%) followed by Verkhoyansk (29.5%), Oymyakon (26.2%) and Ostrov Kotelnyj (16.3%) (Fig. 2).

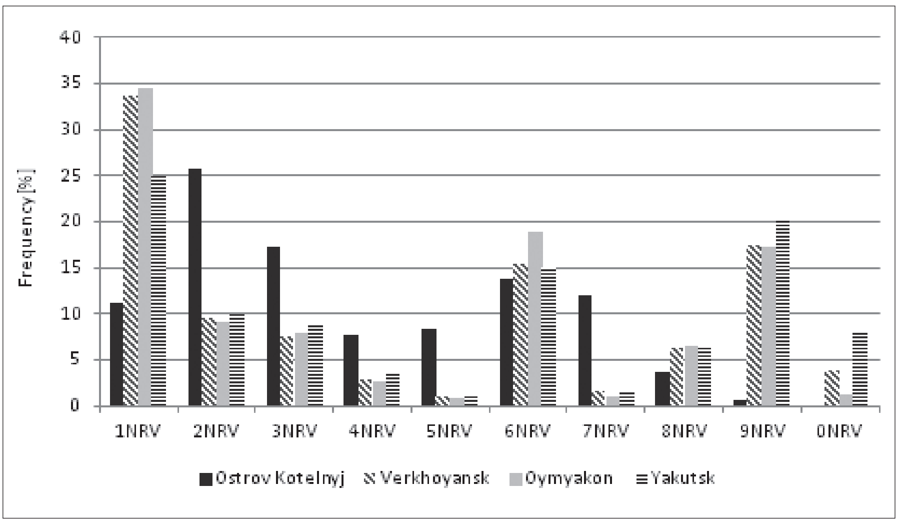

Fig. 2. Frequency [%] of occurrence of weather groups at selected stations in the period Dec 1999 to Nov 2013

The distribution of weather group frequency at the selected stations in each month is presented in Figures 3–6. Their analysis shows that no single weather group was recorded across all months of the year at any of the selected stations. In Ostrov Kotelnyj exceptionally frosty (2NRV) and very frosty weather (3NRV) occupied the largest part of the year, i.e. from October to May, whereas very warm weather (9NRV) occurred for the shortest period, being observed only in the summer months, from

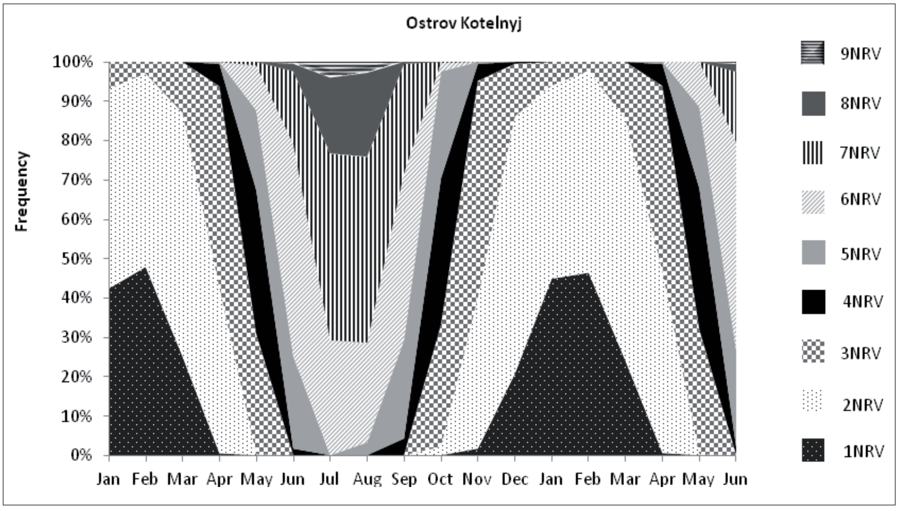

Fig. 3. Annual structure of groups of weather in Ostrov Kotelnyj (Dec 1999 to Nov 2013)

April to July. In Verkhoyansk, Oymyakon and Yakutsk, the weather which lasted for the longest period of the year was transitional (frost-thaw) weather. In Verkoyansk it occurred in the period of March to November; in Oymyakon, from March to October, and in Yakutsk from March to June

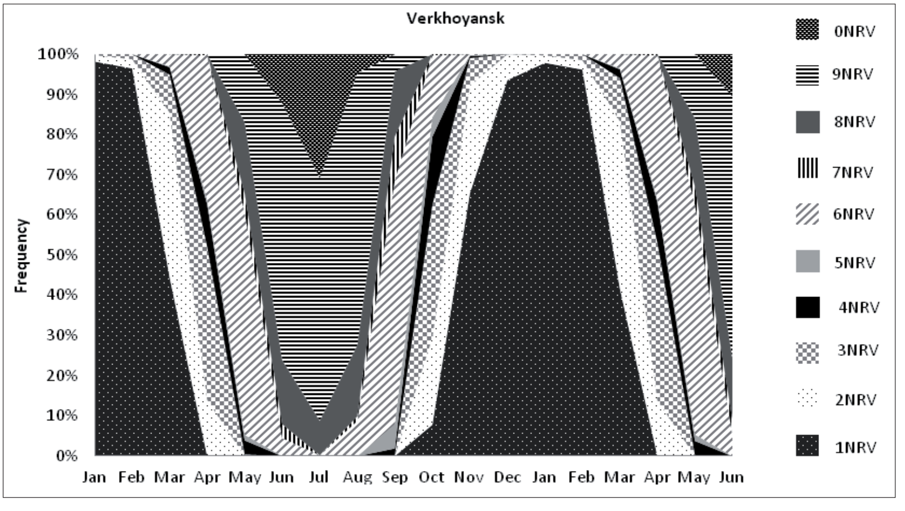

Fig. 4. Annual structure of groups of weather in Verkhoyansk (Dec 1999 to Nov 2013)

and August to November. One group of weather (exceptionally warm 0NRV) is also revealed in all three of the continental stations as least likely to occur. In Verkhoyansk and Oymyakon it was limited to only three months (June to August) and in Yakutsk to four months (May to August). In addition, in Yakutsk for four months of the year moderately frosty weather (5NRV) occurred, from March to April and from October to November.

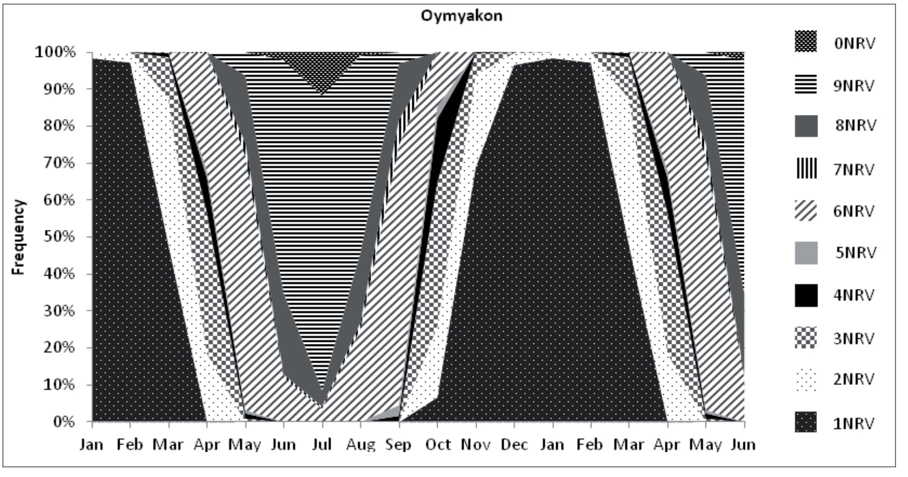

Fig. 5. Annual structure of groups of weather in Oymyakon (Dec 1999 to Nov 2013)

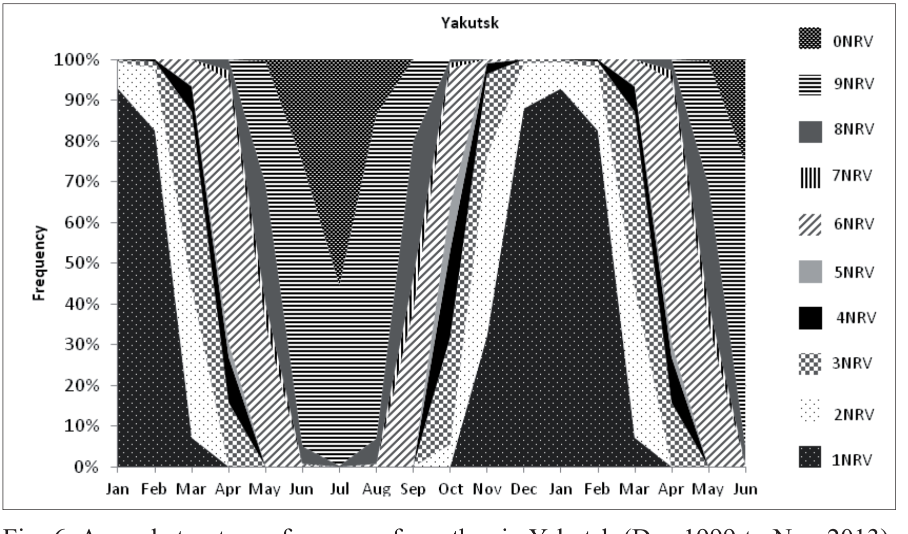

Fig. 6. Annual structure of groups of weather in Yakutsk (Dec 1999 to Nov 2013)

Frequency of occurrence of weather classes

The weather class is a unit of classification which expresses the visual perception of the weather, since it comprises all days characterized by similar conditions of cloudiness, precipitation and wind, but not air temperature. Out of the 54 possible weather classes, the greatest number was observed at the Ostrov Kotelnyj station, being 30 classes. In the research period, 20 of them occurred in Oymyakon, and 17 in Verkhoyansk. The least diverse structure of weather classes was in Yakutsk, with only 15 recorded weather classes. At all of the stations a mere few classes constitute the core of the structure of weather classes (70% of the observations). In the case of Ostrov Kotelnyj, five classes characterise a total of more than 70% of the frequency. They are as follows: cloudy weather with precipitation and a light breeze (311) at 24.2%; cloudy weather without precipitation and with a light breeze (301) at 19.8%; a partly clouded sky, without precipitation and with a light breeze (201) at 15.1%; clear weather without precipitation and with a light breeze (101) at 8.9%; and cloudy weather with precipitation and a strong breeze (313) at 4.6%.

It was also calculated that, in the New Siberian Islands, up to 14 weather classes occur with a frequency of less than 1%, and among those, 9 classes with a frequency of less than 0.4% do not appear annually but occur only in some years. The numbers of classes appearing in selected years are 6 for Oymyakon and a mere 2 for Verkhoyansk and Yakutsk. In Verkoyansk and Oymyakon 3 most often recorded weather classes reoccur. They are: a partly clouded sky, with no precipitation and calm or light air (200, 23.6% and 21.6% respectively); clear weather, no precipitation and calm or light air (100, 19.7%, 11.5% respectively); and cloudy weather with precipitation, and calm or light air (310, 12.1% and 13.8%). All of them constitute about half of the observed weather classes. In Yakutsk, the most frequently occurring weather was cloudy with no precipitation and calm or light air (300, 23.1%). The following weathers occurred less frequently: cloudy without precipitation and with light breeze (301, 18.9%), cloudy with precipitation and calm or light air (310, 15.8%), and cloudy with precipitation and with a light breeze (311, 13.9%). In total, they occurred during more than 70% of the days of the research period.

By analysing the frequency of the weather classes in terms of the type of cloudiness, it can be observed that the clear weather appeared least often at all of the stations in the analysed period. Clear days constituted 13.3% in Ostrov Kotelnyj, 22.6% in Verkhoyansk, 13.1% in Oymyakon, and only 4.4% in Yakutsk. Weather with a partly clouded sky prevailed only in Verkhoyansk (43.6%). In Oymyakon it reached a similar value of 42.1%, but it was slightly exceeded by cloudy weather (44.8%). A similar type of cloudiness was also predominant in Yakutsk (74.4%) and Ostrov Kotelnyj (60.1%).

Weather without precipitation occurred at the selected stations far more frequently (approximately 60% of the cases) than weather with precipitation. Meanwhile, comparing the distribution of weather class frequency in terms of wind, days with the greatest wind speed (weather with strong breeze) were most common at the Arctic station of Ostrov Kotelnyj, with a frequency of 11.7%. At this station, however, the predominant weather was with a light breeze (71.8%). At the other stations, more than half of the days of the study period were characterized by calm weather (Table 2).

Table 2. Frequency [%] of occurrence of weather classes at selected stations in the period Dec 1999 to Nov 2013

No	Ostrov Kotelnyj			Verkhoyansk			Oymyakon			Yakutsk		
	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency
1	311	24.2	24.2	200	23.6	23.6	200	21.6	21.6	300	23.1	23.1
2	301	19.8	44.0	100	19.7	43.3	310	13.8	35.3	301	18.9	42.1
3	201	15.1	59.1	310	12.1	55.4	100	11.5	46.9	310	15.8	57.9
4	101	8.9	68.0	300	8.7	64.1	311	10.7	57.6	311	13.9	71.8
5	313	4.6	72.6	210	8.1	72.3	201	10.3	67.9	200	9.3	81.1
6	211	3.7	76.3	201	8.1	80.3	300	9.1	77.1	201	9.1	90.2
7	314	3.0	79.3	311	6.1	86.5	301	8.9	86.0	100	2.7	92.9
8	303	2.5	81.8	301	5.4	91.8	210	6.1	92.1	101	1.5	94.4
9	100	2.5	84.3	101	2.3	94.1	211	2.2	94.2	312	1.3	95.8
10	203	2.3	86.6	211	1.9	96.0	101	1.3	95.5	302	1.2	97.0

Table 2 (Continued)

No	Ostrov Kotelnyj			Verkhoyansk			Oymyakon			Yakutsk		
	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency	Class of weather	Frequency	Cumulative frequency
11	200	2.1	88.6	202	1.4	97.4	312	1.2	96.7	211	1.0	98.0
12	300	1.5	90.2	302	0.8	98.2	202	1.1	97.8	210	0.9	98.9
13	304	1.5	91.7	312	0.6	98.8	302	0.9	98.7	202	0.8	99.7
14	103	1.4	93.1	212	0.5	99.3	212	0.5	99.2	212	0.2	99.9
15	204	1.2	94.3	110	0.5	99.8	110	0.3	99.5	102	0.1	100.0
16	310	1.1	95.4	102	0.1	99.9	203	0.2	99.7	-	-	-
17	213	0.9	96.3	111	0.1	100.0	303	0.1	99.8	-	-	-
18	104	0.8	97.1	-	-	-	313	0.1	99.9	-	-	-
19	214	0.7	97.8	-	-	-	213	0.1	99.9	-	-	-
20	210	0.5	98.3	-	-	-	102	0.0	100.0	-	-	-
21	312	0.4	98.7	-	-	-	-	-	-	-	-	-
22	111	0.3	99.0	-	-	-	-	-	-	-	-	-
23	302	0.3	99.3	-	-	-	-	-	-	-	-	-
24	113	0.2	99.5	-	-	-	-	-	-	-	-	-
25	202	0.2	99.7	-	-	-	-	-	-	-	-	-
26	212	0.1	99.8	-	-	-	-	-	-	-	-	-
27	102	0.1	99.9	-	-	-	-	-	-	-	-	-
28	316	0.0	99.9	-	-	-	-	-	-	-	-	-
29	206	0.0	99.9	-	-	-	-	-	-	-	-	-
30	215	0.0	100.0	-	-	-	-	-	-	-	-	-

Frequency of occurrence of weather types

The weather type specifies days with an identical description of all the four meteorological elements. Of the theoretically distinguished 480 weather types, the greatest number during the research period was observed in the New Siberian Islands, at 185. At the other stations their number is much smaller and alike (Verhoyansk, 128; Oymyakon, 129; Yakutsk, 124). The majority of the recorded weather types occurred with low frequency. The core of the structure of the weather types (70% of observations) for the studied stations ranges from 25 types for Ostrov Kotelnyj, through 24 for Verkhoyansk and 23 for Yakutsk, to just 19 for Oymyakon. At Ostrov Kotelnyj, the three predominant weather types are: exceptionally frosty, with a partly clouded sky, with no precipitation and a light breeze (2201, 6.7%); transitional (frost-thaw), cloudy, with precipitation and a light breeze (6311, 5.2%); and moderately warm, cloudy, with precipitation and a light breeze (7311, 5.0%). In Verkhoyansk and Oymyakon, the two most common types of weather are the same, namely, i) extremely frosty and clear weather, no precipitation and calm (1100), which represents 12.5% of the days in Verkhoyansk, and 7.8% in Oymyakon, and ii) extremely frosty and partly clouded weather without precipitation and calm (1200) occurring with a frequency of 9.8% in Verkhoyansk, and 11.6% in Oymyakon. The aforementioned weather conditions together with extremely frosty weather, partly clouded, with precipitation and calm (1210) in Verkhoyansk, and also very frosty weather, cloudy, with precipitation and calm (1310) in Oymyakon comprise more than one quarter of the days at these stations. Similarly, in Yakutsk the three most frequent weather types constitute more than 25% of the days. These are: very frosty weather, cloudy, with no precipitation and calm or light air (1300, 12.2%); very frosty, cloudy, with precipitation and calm or light air (1310, 7.7%); and very warm, cloudy, without precipitation and with a light breeze (9301, 6.1%). A large number of weather types included in the structure of weather conditions does not necessarily signify a rich diversity of weather in a given area (Table 3). In the case of the examined station, it rather indicates the monotony of weathers, as evidenced by the small number of the weather types forming the core of the structure, and a very large number of them of a marginal proportion. As many as 38 weather types for Ostrov Kotelnyj, 21 for Oymyakon and 14 for both Verkhoyansk and Yakutsk occurred only once during the research period. These types are of very little importance in forming the structure of the weather at the selected stations. Nevertheless, they affect the increase of the inter-annual and inter-monthly variability in the structure of the weather types.

Table 3. Frequency [%] of occurrence of dominant weather types at selected stations in the period Dec 1999 to Nov 2013

No	Ostrov Kotelnyj			Verkhoyansk			Oymyakon			Yakutsk		
	Type of weather	Frequency	Cumulative frequency	Type of weather	Frequency	Cumulative frequency	Type of weather	Frequency	Cumulative frequency	Type of weather	Frequency	Cumulative frequency
1	2201	6.7	6.7	1100	12.5	12.5	1200	11.6	11.6	1300	12.2	12.2
2	6311	5.2	11.9	1200	9.8	22.3	1100	7.8	19.4	1310	7.7	19.9
3	7311	5.0	16.9	1210	4.9	27.2	1310	6.8	26.2	9301	6.1	25.9
4	3311	4.8	21.6	6200	4.1	31.3	6201	4.2	30.3	6301	4.4	30.4
5	6301	4.2	25.8	1310	4.0	35.2	1210	4.1	34.5	9311	4.0	34.4
6	2101	4.1	29.9	9200	2.9	38.1	9201	3.8	38.3	2310	3.3	37.7
7	7301	3.6	33.6	9201	2.9	41.0	1300	3.8	42.1	9201	2.9	40.5
8	1101	3.5	37.1	2200	2.6	43.6	6301	3.5	45.6	6300	2.5	43.0
9	5311	3.2	40.3	6201	2.3	45.9	9311	3.5	49.1	0301	2.5	45.5
10	2301	2.9	43.2	3200	2.2	48.1	6200	3.1	52.2	9300	2.4	47.9
11	5301	2.8	46.0	2310	2.2	50.4	8311	2.7	54.9	6201	2.2	50.1
12	3301	2.8	48.8	2100	2.1	52.4	2310	2.5	57.4	1200	2.2	52.3
13	1201	2.7	51.5	6100	2.0	54.4	2200	2.3	59.7	2300	2.1	54.4
14	3201	2.7	54.2	9311	1.9	56.2	9301	2.3	62.0	8301	2.1	56.4
15	4311	2.6	56.8	1300	1.7	58.0	6311	2.2	64.2	8311	1.9	58.3
16	2311	2.3	59.1	6300	1.7	59.6	3200	2.0	66.3	6200	1.9	60.2
17	4301	2.0	61.1	9310	1.7	61.3	9200	1.8	68.1	3311	1.7	61.9
18	2211	1.7	62.8	9300	1.5	62.8	2100	1.5	69.7	0300	1.6	63.5
19	1100	1.7	64.5	9301	1.5	64.3	6300	1.5	71.1	6311	1.5	65.0
20	2200	1.1	65.6	3100	1.4	65.7	-	-	-	2200	1.4	66.5
21	6313	1.0	66.6	6301	1.4	67.1	-	-	-	3310	1.4	67.9
22	7313	1.0	67.5	2210	1.1	68.2	-	-	-	3200	1.4	69.3
23	2203	1.0	68.5	3310	1.1	69.4	-	-	-	1311	1.3	70.6
24	3211	1.0	69.5	8310	1.1	70.5	-	-	-	-	-	-
25	3313	1.0	70.5	-	-	-	-	-	-	-	-	-

In order to investigate the weather variability at the Siberian stations, the number of weather types occurring in individual decades of the year was employed. The greater this value is, the greater the likelihood of a high variability of weather conditions from year to year. Fewer than 10 weather types in a particular decade indicates that this type lasts longer than one day, and thus reoccurs in a certain decade every year.

What characterises the diversity of the number of the weather types at the station of Ostrov Kotelnyj is the fact that in all the decades it is higher than 22. This indicates a high interannual changeability of the weather during any ten-day period. The greatest number of types, i.e. 41, was recorded in the 1st and 34th decade, whereas the smallest, which was 22, occurred in the 29th. A smaller number of weather types is noticeable in the autumn decades (from 25 to 29), which points to a greater stability of weather from year to year during this period.

The other stations are characterised by several decades of stable weather conditions, during which the number of recorded weather types is lower than 10, which means that they reoccur every year. For Verkhoyansk it is the 1st, 2nd, 4th, and 5th decade of the year. In Oymyakon it is the 1st, 2nd, 3rd, 35th and 36th, which is the winter period at the end and beginning of the year, whereas in Yakutsk it is the 2nd decade of January. Undoubtedly the decreased number of weather types, and hence the greater stability of the weather during the winter period, especially in Verkhoyansk and Oymyakon, resulted from the fact that these places are located close to the centre of the Asiatic High. A greater variation in the number of the observed types (more than 30) occurs in the 12th to 18th decades in Verkhoyansk, and in the 15th to 17th decades in Oymyakon. For both of the stations the 25th decade is also particularly noteworthy for its considerable interannual variability (Fig. 7).

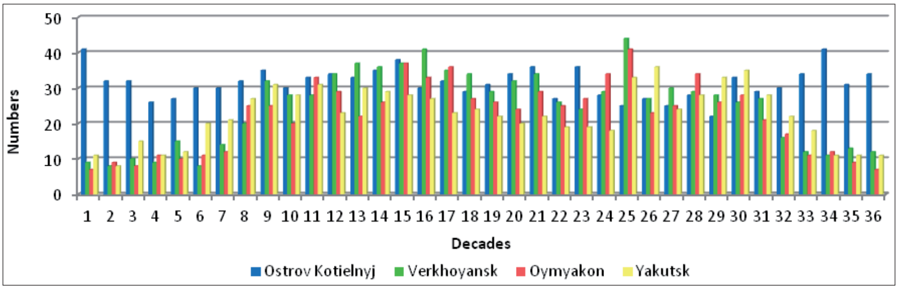

Fig. 7. Number of weather types at selected stations in consecutive decades of the year (Dec 1999 to Nov 2013)

Length and occurrence of dominant weather type sequences

A "sequence" of a particular weather type comprises at least two consecutive days of the same weather type. The adopted unit of measurement of its length is the day. Analysis of the dominant weather type sequences allows the types of weather that increase stability of meteorological conditions to be determined. According to the calculations, the majority of sequences of the same dominant weather type were observed in Oymyakon (827), followed by Yakutsk (800), Ostrov Kotelnyj (741), whereas the fewest were observed in Verkhoyansk (710). Their length ranged from 2 to 11 days in Ostrov Kotelnyj, 2 to 13 in Verkhoyansk, 2 to 9 in Oymyakon, and 2 to 12 in Yakutsk. Not all of the weather types occurring at the observed stations formed sequences. There were sequences of consecutive days with the same weather conditions for 83 weather types on Kotelnyj Island, 65 types in Verkhoyansk, 57 in Oymyakon, and 61 in Yakutsk. The other weather types appeared only on individual days, and thus contributed to greater variability of the weather. Tables 4, 5, 6 and 7 present the weather types which stabilized weather conditions to the greatest extent. The several-day-long sequences of these weather types constituted about 75% of all those recorded. For Ostrov Kotelnyj and Yakutsk there were 18 types, while for Verkhoyansk and Oymyakon there were 16 and 15, respectively. At each of the stations, the greatest number of sequences of dominant weather types was of the weather type with the largest annual frequency.

Table 4. Length and occurrence of dominant weather types in sequences in Ostrov Kotelnyj (Dec 1999 to Nov2013)

No	Weather type	Number of days within sequence										Sum	Cumulative sum
		2	3	4	5	6	7	8	9	10	11		
1	2201	**6.6**	**1.6**	**0.5**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	8.9	8.9
2	7311	**4.5**	**2.6**	**0.4**	**0.1**	**0.1**	0.0	0.0	**0.1**	0.0	0.0	7.8	16.7
3	3311	**4.6**	**1.6**	**0.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	23.6
4	6311	**3.8**	**1.6**	**1.1**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	6.7	30.4
5	6301	**4.3**	**0.8**	0.0	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	5.3	35.6
6	2101	**3.4**	**1.3**	**0.3**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	5.1	40.8
7	1101	**3.4**	**0.7**	**0.3**	**0.4**	0.0	0.0	0.0	0.0	0.0	0.0	4.7	45.5
8	7301	**2.4**	**1.2**	**0.3**	**0.0**	0.0	0.0	**0.1**	0.0	0.0	**0.1**	4.2	49.7

Table 4 (Continued)

No	Weather type	Number of days within sequence										Sum	Cumulative sum
		2	3	4	5	6	7	8	9	10	11		
9	4311	**1.9**	**0.8**	**0.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	52.9
10	5301	**2.3**	**0.7**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	56.1
11	1201	**2.2**	**0.7**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	59.2
12	3201	**2.7**	**0.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	62.4
13	5311	**1.9**	**0.5**	**0.1**	0.0	**0.1**	**0.1**	0.0	0.0	0.0	0.0	2.8	65.2
14	2301	**2.0**	**0.3**	0.0	**0.1**	0.0	**0.1**	0.0	0.0	0.0	0.0	2.6	67.7
15	3301	**1.8**	**0.7**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	70.3
16	2311	**1.6**	**0.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	72.5
17	1100	**1.5**	**0.3**	0.0	**0.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	2.0	74.5
18	4301	**0.9**	**0.3**	0.0	**0.3**	**0.1**	0.0	0.0	0.0	0.0	0.0	1.6	76.1
	Sum	**51.7**	**16.6**	**4.9**	**1.8**	**0.5**	**0.3**	**0.1**	**0.1**	0.0	**0.1**	76.1	

Table 5. Length and occurrence of dominant weather type sequences in Verkhoyansk (Dec 1999 to Nov 2013)

No	Weather type	Number of days within sequence												Sum	Cumulative sum
		2	3	4	5	6	7	8	9	10	11	12	13		
1	1100	**11.4**	**3.4**	**3.7**	**1.5**	**0.8**	**0.3**	**0.1**	**0.3**	0.0	0.0	0.0	0.0	21.5	21.6
2	1200	**8.7**	**2.8**	**1.5**	**0.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	34.9
3	6200	**4.2**	**1.1**	**0.4**	**0.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	41.0
4	1310	**3.7**	**0.8**	**0.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	46.1
5	1210	**3.5**	**0.6**	**0.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	50.7
6	9200	**3.0**	**0.6**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	54.4
7	2100	**1.3**	**0.8**	**0.3**	**0.4**	0.0	0.0	0.0	0.0	**0.1**	0.0	0.0	0.0	3.0	57.3
8	3200	**1.5**	**1.0**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	60.0
9	9201	**2.1**	**0.4**	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	62.5
10	2310	**1.5**	**0.3**	**0.4**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	64.9
11	2200	**2.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	67.2
12	3100	**1.0**	**0.6**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	69.0
13	6300	**1.1**	**0.6**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	70.8
14	6201	**1.1**	**0.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	72.5
15	9310	**1.3**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	74.1
16	6100	**0.7**	**0.4**	0.0	**0.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**	1.5	75.6
	Sum	**48.3**	**14.4**	**8.2**	**2.5**	**1.3**	**0.3**	**0.1**	**0.3**	**0.1**	0.0	0.0	**0.1**	75.6	

Table 6. Length and occurrence of dominant weather type sequences in Oymyakon (Dec 1999 to Nov 2013)

No	Weather type	The number of days within sequence								Sum	Cumulative sum
		2	3	4	5	6	7	8	9		
1	1200	**9.7**	**4.1**	**2.1**	**0.7**	**0.1**	0.0	0.0	0.0	16.7	16.7
2	1100	**5.4**	**2.3**	**1.7**	**0.6**	**0.6**	**0.1**	**0.1**	**0.1**	11.0	27.7
3	1310	**6.0**	**1.9**	**0.7**	**0.1**	**0.1**	**0.1**	**0.1**	0.0	9.2	36.9
4	6201	**3.1**	**0.7**	**0.2**	**0.1**	0.0	0.0	0.0	0.0	4.2	41.1
5	9311	**3.1**	**0.4**	**0.5**	**0.1**	0.0	0.0	0.0	0.0	4.1	45.2
6	9201	**2.3**	**1.1**	**0.4**	**0.1**	**0.1**	0.0	0.0	0.0	4.0	49.2
7	6301	**2.7**	**0.6**	**0.4**	**0.1**	0.0	**0.1**	0.0	0.0	3.9	53.1
8	1300	**2.4**	**1.1**	**0.1**	0.0	0.0	0.0	0.0	0.0	3.6	56.7
9	1210	**2.7**	**0.4**	**0.1**	0.0	0.0	0.0	0.0	0.0	3.1	59.9
10	2310	**2.4**	**0.6**	**0.1**	0.0	0.0	0.0	0.0	0.0	3.1	63.0
11	3200	**1.8**	**0.8**	**0.4**	0.0	0.0	0.0	0.0	0.0	3.0	66.0
12	6200	**2.5**	**0.4**	**0.1**	0.0	0.0	0.0	0.0	0.0	3.0	69.0
13	2200	**1.9**	**0.7**	**0.1**	0.0	0.0	0.0	0.0	0.0	2.8	71.8
14	8311	**1.8**	**0.8**	0.0	**0.1**	0.0	0.0	0.0	0.0	2.8	74.6
15	2100	**1.0**	**0.7**	**0.1**	**0.2**	0.0	0.0	0.0	0.0	2.1	76.7
	Sum	**49.0**	**16.7**	**7.0**	**2.3**	**1.0**	**0.4**	**0.2**	**0.1**	76.7	

Table 7. Length and occurrence of dominant weather type sequences in Yakutsk (Dec 1999 to Nov 2013)

No	Weather type	Number of days within sequence											Sum	Cumulative sum
		2	3	4	5	6	7	8	9	10	11	12		
1	1300	**5.4**	**3.4**	**1.9**	**2.3**	**0.6**	**0.9**	**0.3**	**0.4**	**0.3**	**0.4**	**0.3**	15.9	15.9
2	1310	**6.5**	**2.5**	**1.4**	**0.8**	0.0	0.0	**0.1**	0.0	0.0	0.0	0.0	11.3	27.1
3	9301	**5.1**	**2.4**	**0.5**	**0.3**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	8.4	35.5
4	6301	**3.0**	**1.4**	**0.3**	**0.1**	0.0	0.0	**0.1**	0.0	**0.1**	0.0	0.0	5.0	40.5
5	9311	**3.5**	**0.6**	**0.3**	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	45.0
6	2310	**2.1**	**0.8**	**0.5**	**0.3**	**0.3**	0.0	0.0	0.0	0.0	0.0	0.0	3.9	48.9

Table 7 (Continued)

No	Weather type	Number of days within sequence											Sum	Cumulative sum
		2	3	4	5	6	7	8	9	10	11	12		
7	0301	2.0	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	52.0
8	1200	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	54.9
9	8301	2.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	57.4
10	9201	2.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	59.8
11	0300	1.8	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	62.1
12	6300	1.9	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	64.4
13	3311	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	66.4
14	6200	1.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	68.4
15	2200	1.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	70.3
16	3310	1.0	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	72.0
17	9300	1.1	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.8	73.8
18	6201	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	75.4
	Sum	46.9	14.9	5.8	4.0	1.1	0.9	0.5	0.4	0.4	0.4	0.3	75.4	

At all of the stations, two-day sequences predominated. In Ostrov Kotelnyj they amounted to 72.3% of all recorded sequences, 69.3% in Verkhoyansk, 67.8 in Oymyakon and 66.5% in Yakutsk. Next in terms of the frequency of occurrence were three-day sequences. They occurred with a frequency of 19.3% in Ostrov Kotelnyj, 16.2% in Verkhoyansk, 19.8% in Oymyakon, and 18.5% in Yakutsk. The frequency of four-day sequences was significantly lower and came to 5.4% in Ostrov Kotelnyj, 9.6% in Verkhoyansk, 8.1% in Oymyakon, and 6.9% in Yakutsk. The most five-day sequences appeared in Yakutsk, accounting for 4.3% of observed sequences. At the other three stations, the frequency of five-day sequences did not exceed 2.7%. Six-day sequences and longer had a frequency below 1.3%. Further research should concern itself with the seasonal distribution of the frequency of the sequences of dominant weather types.

Discussion of results and conclusions

This paper describes the structure of weather types at selected Siberian synoptic stations. In accordance with the principles of the classification of weather types by Ferdynus (1997, 2004, 2013), for each of the stations, groups, classes, and types of weather were determined, and sequences of days with the same type of weather were calculated.

The analysis shows a high variability of weather conditions at all of the stations during the research period. This is expressed primarily in the large number of recorded weather types, and with that, their individual low frequencies. The greatest number of observed weather types was seen at Ostrov Kotelnyj (185). At this station up to 20% of the observed weather types appeared only once in the research period. According to the research of Ferdynus (2013) conducted for the years 1980–2009, an even greater number of weather types (216) was recorded in the Atlantic sector of the Arctic in Hornsund at Spitsbergen. However, fewer occurred once in the study period than in Ostrov (only 14% of the observed types). The core of the structure of the weather types (accounting for two thirds of the year) comprises 21 types in Ostrov Kotelnyj and Verkhoyansk, 20 types in Yakutsk and only 16 in Oymyakon. For Spitsbergen this number is considerably higher and totals 32 types (Ferdynus 2013). The most frequently occurring weather type in Ostrov Kotelnyj was exceptionally frosty weather, with a partly clouded sky, no precipitation and light wind (2201). At the other stations, the weather types of highest frequency were very similar to each other, and differed only in the degree of cloudiness. In Verkhoyansk the weather was extremely frosty and clear weather without precipitation and calm (1100), while in Oymyakon it was extremely frosty, with a partly clouded sky, no precipitation and calm (1200), and in Yakutsk it was extremely frosty, cloudy, with no precipitation and calm (1300). In Horsund the most frequent was moderately warm, cloudy, with precipitation and light breezy weather (7311). The number of weather types in different decades of the year shows some seasonal fluctuations. In Ostrov Kotelnyj the period of most stable weather conditions was observed in autumn, when the number of weather types was lower than average. This is probably associated with a shift to the north by the Asiatic High, on the edge of which the Ostrov Kotelnyj station was then situated. At the other stations, a reduced number of weather types was recorded in winter, which was also influenced by a strong Asiatic

High with its centre over Verhoyansk (Atlas Arktiki 1985). At Spitsbergen the lowest numbers of weather types occurred in July, while the greatest occurred in the cold season of the year, especially during the polar night. This is probably connected with the vigorous cyclonic activity, which causes frequent advection of the air masses both from the Arctic area and from the lower latitudes (Ferdynus 2013).

There was also a large number of weather classes reflecting visual perception of weather conditions at the studied stations. At each of the stations, days without precipitation prevailed. Similarly, at Spitsbergen they are characterized by a slight predominance during the year (Ferdynus 2013). Higher wind speeds were recorded on the New Siberian Islands. In Verkhoyansk, Oymyakon and Yakutsk, days with calm or light air predominated. In Hornsund, as in the New Siberian Islands, there was a distinct predomination of light breezy weather classes (Ferdynus 2013). The degree of cloudiness is very diverse within the research areas. In Ostrov Kotelnyj, Yakutsk and Hornsund most days of the year were cloudy, whereas in Verkhoyansk and Oymyakon they were partly clouded.

All of the stations are also characterized by a large range of recorded weather groups. In Verkhoyansk, Oymyakon and Yakutsk, all 10 of the 10 weather groups likely to occur did in fact occur. In Hornsund 10 groups of weather were also observed, but one of them marked as 9NRV occurred only once in the period analyzed by Ferdynus (2013). Therefore, daily average temperatures recorded in these places range from -40^{o}C to 29.9^{o}C in the course of the year. In Ostrov Kotelnyj, the only days which did not occur were days with the warmest group of weather (0NRV). At each of the stations, the prevalent weather was frosty (1NRV, 2NRV, 3NRV, 4NRV and 5NRV). In Ostrov Kotelnyj, the weather which lasted for the longest period over the year (8 months) was exceptionally frosty (2NRV) and extremely frosty (3NRV), whereas in Verkhoyansk, Oymyakon and Yakutsk it was transitional weather, frost-thaw (6NRV) lasting for 9, 8 and 8 months, respectively. The role of the warm weathers (7NRV, 8NRV, 9NRV and 0NRV) in shaping the annual structure of the weather types is greatest in Yakutsk (more than 1/3 of the days of the year) and Verkhoyansk and Oymyakon (slightly less than 1/3 of the days of the year). The smallest percentage of them occurred on the New Siberian Islands. The presented differences in structure of weather types between stations Verkhoyansk, Oymyakon, Yakutsk, Ostrov Kotelnyj and Hornsund reflect the differences in the formation of weather conditions in the continental climate of Siberia, the continental climate of the Arctic and the marine climate of Spitsbergen.

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